Conclusion: Our results confirm the validity of PCXMC with rotational module also for particular geometrical conditions; patient dose can be evaluated based on patient equivalent diameter.

EP-1619

Ovaries and uterus Equivalent dose to in patients treated for Hodgkin Lymphoma with mediastinal RT

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Purpose or Objective: Hodgkin's lymphoma (HL) is one of the most curable types of cancer. Most HL patients are young (average age of 32 years); long-term side effects of the treatment are becoming increasingly important. Infertility after treatment could have a high psychosocial burden for young patients. More, HL is one of the most common malignancies diagnosed during pregnancy. The aim of the present study is to measure dose to ovaries and uterus, during supra-diaphragmatic radiotherapy performed with different techniques (3DRT, IMRT, VMAT and helical IMRT-Tomotherapy®).

Material and Methods: Dose measurements were performed using the plans of four different female patients, in reproductive age. The patients have been treated with chemotherapy and mediastinum irradiation (isocenter dose 30 Gy). An adult anthropomorphic Alderson Rando phantom (*Rando phantom*) was utilized for woman simulation. For each patient the *Rando phantom* TC-scan was matched with the PET/CT. Doing it, an approximate patient specific isocenter position on the *Rando phantom* and a relative position of ovaries and uterus in terms of phantom slices were identified. Treatment planning images and diagnostic whole body PET/CT were fused by means of Velocity AI 3.0 ®. Calcium fluoride thermoluminescent dosimeters, TLD-100, were used for dose measurements, 5 TLDs were used for every measurement. Patient's treatment was simulated in 4 different techniques: 3DRT, IMRT, VMAT and helical IMRT-Tomotherapy®. To compare the results paired T student test was used.

Results: The equivalent doses to left ovary, right ovary and uterus, were respectively 16 mSV (range 5-19), 10 mSV (range 8-14) and 9 mSV (range 7-12) with 3DRT techniques; 15 mSV (range 7-23), 11.5 mSV (range 6-17) and 13 mSV (range 6-18) with VMAT; 14 mSV (range 6-23), 14 mSV (range 5-22) and 13 mSV (range 9-20) with IMRT and 54,5 mSV(range 44-70), 50mSV (range 40-72) and 56 mSV (range 33-67) with helical Tomotherapy®. Helical Tomotherapy® doses were significantly higher than the other three ($p<10^{-8}$ for all three tests). IMRT results were significantly higher than VMAT and 3D (p=0,023 and 0,004 respectively). VMAT and 3D results are not statistically different one from each other (p=0,42).

Conclusion: All the techniques give a dose to ovary and uterus well below 100 mSv. This is the dose considered safe in terms of deterministic effects on embryo or foetus and with a relatively low risk of stochastic effect. Helical Tomotherapy® and IMRT give higher gonads dose as compared to other techniques. The implications of these data may be relevant also for patients in the very early stages of their pregnancy.

EP-1620

Accuracy of cone beam computed tomography while decreasing dose to patient

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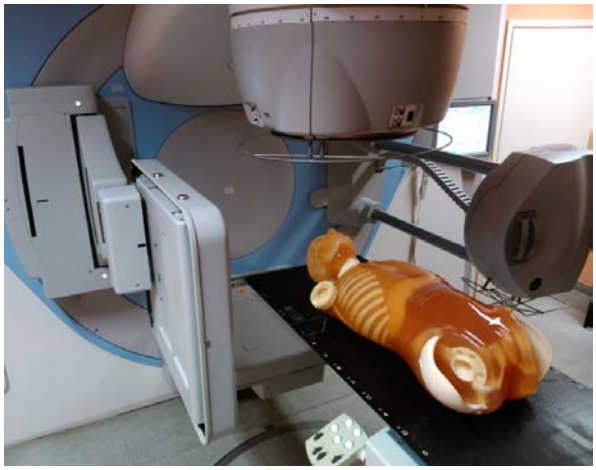
Purpose or Objective: The main interest was to decrease the localization CBCT scan dose in lung area since the dose deposited by CBCT contributes fully in increasing low dose volume in lung which is arguably the main indicator of radiotherapy induced pneumonitis and fibrosis. Several scanning protocols with decreasing dose were investigated to confirm that the localization accuracy is not reduced.

Material and Methods: In this work it was investigated how do physical scanning parameters - voltage, current and time - affect the automatic image registration of the localization CBCT using XVI 4.5 system from Elekta. A Cathphan 504 phantom was used for image quality measurements and an anthropomorphic phantom PBU-50 was used to verify localization accuracy. 21 scanning protocols with decreasing dose and two different automatic registration algorithms (Grey value and Bone) were analysed in lung area. Deliberate shifts with different size and direction were introduced. Image quality of acquired scans was analysed using modular transfer function (MTF), uniformity and low contrast visibility. Relative scan dose was measured with centered Farmer chamber.



Results: It was found that CBCT system is rather insensitive to the size (max 20 mm) and direction of the deliberate shift of the phantom. Precision of the correction shifts were within 0,5 mm that is in the limit of estimated uncertainty. It was observed that the MTF was insensitive to physical scanning parameters and much more dependant on image reconstruction protocol parameters. Uniformity improved and low contrast visibility decreased while lowering dose of scanning protocol. The CBCT system under investigation showed excellent precision for positioning the phantom even while dose of scanning protocol was reduced ~90%. On the other hand – low contrast visibility decreased and would most likely limit the amount of dose redaction to acceptable level that is still to be determined.

Conclusion: This work showed that CBCT is a very accurate localization method even in conditions where scanning dose was decreased to ~10% of initial dose. It is necessary to further assess the suitability of new low dose protocols qualitatively to develop acceptable clinical scanning protocols as well as to investigate possibility to improve reconstruction protocols.

EP-1621

Automated extraction and management of radiotherapy imaging dose data

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Purpose or Objective: To construct a data warehouse of radiotherapy imaging performance data by automatically extracting CT and CBCT acquisition and dose information from the hospital PACS and ARIA oncology management

system (OMS), thus allowing individual patient dose records to be monitored and radiotherapy imaging dose reference levels (DRLs) to be developed.

Material and Methods: DICOM query/retrieve is used to index and fetch CT dose report objects known to the PACS. Protocol information, patient details, CTDI and DLP are extracted. A script runs against the OMS and extracts CBCT activity information, including exposure settings and scan length. All information is converted into a standard format and stored in a data warehouse structured to make data exploration straightforward using readily available reporting and data mining tools. Data can be plotted and tabulated as a function of scanner, linac, operator, day of week, etc. Authorised operators can drill down to the patient, study and series level to understand the pre-treatment and linac imaging performed on individual patients and review the overall imaging dose record. Data can also be presented anonymised or pseudonymised for research, development and audit purposes.

Results: Table 1 shows data volumes and extract timings for a large centre (8 linacs with CBCT). The processing burden to update the data warehouse on a nightly basis is negligible.

Modality	Scanners / Linacs	Time Period	Number of Patients	Number Of Scans	Bulk Extraction Time
CT	3	Jan 2013 – Feb 2015	12,890	20,697	6 hours
CBCT	8	Jan 2013 – Feb 2015	1,898	21,256	5 mins

Table 1: Data volume and data extraction timing details.

Radiotherapy pre-treatment exposures were consistent with the equivalent diagnostic investigations and both were in line with local and national DRLs. There was clear evidence that when more advanced and automated linac imaging equipment is available more CBCTs are acquired (linacs VT1 and VT3 in Figure 1). Optimisation strategies can be studied by reviewing dose information alongside image quality and clinical decision making (see Figure 2, where dose differs between linacs and was deliberately increased when imaging a large patient).

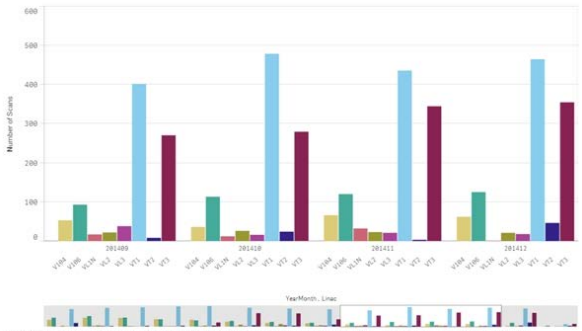

Figure 1: Number of scans per linac as a function of time. Period from September to December 2014 has been selected.

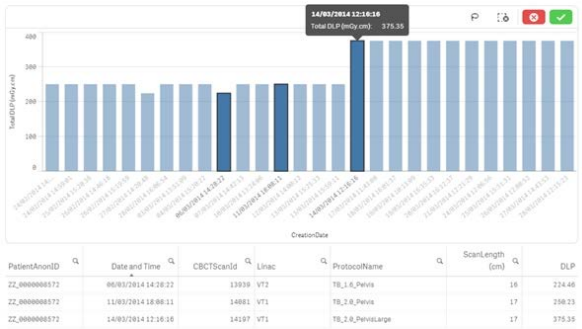

Figure 2: Linac imaging dose record for large patient (pseudonymised). Dose differences between same protocol on different linacs can be observed, along with move to higher dose protocol to boost image quality.

It was found that ARIA does not always correctly record CBCT exposure information, although if linac imaging is protocol driven there is a unique relationship between recorded values and protocol selected. Also, body site information may be coded differently between CT scanners. Data warehouse mapping tables were employed to identify the actual CBCT protocols utilised and standardise site descriptions.

Conclusion: An automated data warehouse empowers professionals who are not IT experts to ask clinically relevant questions of a rich data source of imaging performance and dose information.

EP-1622

Cyberknife® M6TM: peripheral dose evaluation in brain treatments

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Purpose or Objective: Radiosurgery (SRS) and stereotactic radiotherapy (SRT) are known to deliver very high doses per fraction. The corresponding peripheral dose can be a limiting parameter which potentially generates late toxicities. The purpose of this study was to evaluate peripheral dose delivered to healthy tissues such as thyroid and gonads for brain SRS/SRT treatments performed with a Cyberknife® M6TM system.

Material and Methods: Measurements were performed on a Cyberknife® M6TM (Accuray) equipped with fixed and IrisTM collimator systems. Doses were measured with GR200A (LiF:Mg, Cu, P) thermoluminescent dosimeters (TLD). Each TLD was individually calibrated in a 6 MV beam. TLD readings were performed with a PCL3 automatic reader (FIMEL). Firstly, in-vitro measurements were carried out in an anthropomorphic phantom (CIRS ATOM 701-c) for different typical brain treatment plans using different beam apertures (5 mm to 60 mm). Peripheral doses were measured at 24 points distributed from thyroid to gonads on the median line of the phantom (between 15 cm and 82.5 cm from the PTV center). Secondly, in-vivo measurements were performed on 30 patients, in 4 points representative of thyroid, breast, umbilicus and gonads. The number of monitor units (MU) used for treatment plans ranged from 5499 MU to 28900 MU with a mean value of 13737 MU, delivered in 1 to 3 fractions. Results were compared with peripheral dose published for previous Cyberknife® versions. Treatment plans were calculated with Multiplan v5.1.2 (Accuray). Peripheral dose were reported in cGy as percentage of the number of delivered Monitor Units (% of MU).

Results: Peripheral dose varied according to collimator size: 0.043 % of MU at 15 cm for a 5 mm collimator aperture and 0.235 % of MU at 15 cm for a 60 mm collimator aperture. For an intermediate collimator aperture (20 mm), peripheral doses were between 0.062 % of MU at 15 cm and 0.036 % of MU at 40 cm for fixed collimator system and between 0.040 % of MU at 15 cm and 0.029 % of MU at 40 cm for IrisTM collimator system. Table 1 compares our in-vivo measurements with peripheral dose published in the literature on several Cyberknife® models [1,2].

Table 1: Comparison between peripheral dose values measured for 5 Cyberknife versions in brain treatment

Peripheral dose (exprimed in cGy as percentage of the number of delivered Monitor Units (% of MU)						
Device		Cyberknife G4 preshielding	Cyberknife G4 postshielding	Cyberknife VSI preshielding	Cyberknife VSI postshielding	Cyberknife M6
Study		*[1]*		*[2]*		*Our results*
Dose measurement methods		In vivo (10 patients)	In vivo (21 patients)	In vitro		In vivo (31 patients)
Distance range from PTV and localization	[10,24] cm for Thyroid	0.220	0.170	0.160	0.066	0.045
	[28,44] cm for Thorax	-	0.050	0.108	0.048	0.038
	[60,89] cm for Pelvis	0.060	0.050	0.045	0.036	0.022